Fluctuations of rare particles as a measure for chemical equilibration *

S. Jeon, V. Koch, K. Redlich, and X.-N. Wang

In this work, we address the question of number fluctuations of rarely produced particles. We carried out the analysis by solving the master equation,

$$\frac{dP_n}{d\tau} = \varepsilon\left[P_{n-1} - P_n\right] - \left[n^2 P_n - (n+1)^2 P_{n+1}\right] \qquad (1)$$

derived in an earlier paper. The most important aspect of the master equation is that we can treat the conservation laws that govern the rare particles exactly. For instance, the strangeness conservations for kaon prodction at the SIS energy can be treated in this way. In previous papers, some of us explored the consequence of requiring the exact conservation on the behavior of the average multiplicity in equilibrium as well as in evolving systems. In this work, we investigated the time evolution of the second factorial moment $F_2 = \langle N(N-1)\rangle / \langle N\rangle^2$ to explore the possiblity of using it as a non-equilibrium measure.

To cover a wide range of physical phenomena, we studied two extreme cases. (i) The initial population of the rare particle is much larger than the equilibrium population. (ii) The initial population is much smaller. Our main conclusion is that the measurement of F_2 can certainly tell us if the equilibrium has not been reached. Moreover, the approach of the second factorial moment towards the equilibrium depends very much on the initial condition. Assuming that the equilibrium population ε is very small, we see that the smaller initial population results in the approach from above the equilibrium value ($F_2^{\rm eq} = 1/2 + O(\varepsilon)$) and the larger initial population results in the approach from below with a long period of very small F_2. Hence, the experimental value of F_2 can immediately tell us if the initial population was smaller ($F_2^{\rm exp} > 0.5$), larger ($F_2^{\rm exp} < 0.5$, possibly $F_2^{\rm exp} \ll 0.5$) or the system has already reached the equilibrium before the freeze-out ($F_2^{\rm exp} \simeq 0.5$).

The time history of F_2 holds much more information about the system itself. In any experiment, however, we observe only the spectrum at the freeze-out. Still, we can get more information if we correlate factorial moment measurements. For instance, if we correlate the second factorial moment and the average (the first factorial moment), then we can say something about the freeze-out time scale by solving a coupled equations.

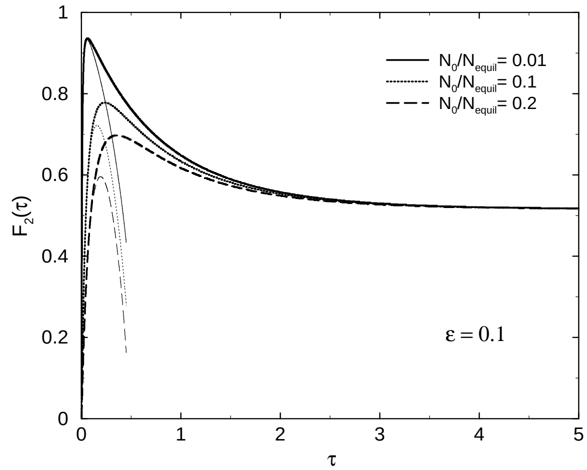

Figure 1: Time evolution of the factorial moment F_2 for several initial particle numbers N_0 (thick lines). The thin lines show the result of the approximate formula . Here $\varepsilon = 1$ has been used.

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